3.1 GENERAL

Recharge devices may take a variety of forms, including porous pavement, infiltration trenches, percolating catch basins, or larger basins which occupy land set aside for the purpose. There are no fundamental differences in the devices, either in the way they control storm runoff, or in the procedure for analyzing performance. The differences are in details such as the size of the basin, the configuration, and the size of the catchment area routed through a particular unit.

Given a specific surface area provided for percolation, and a unit infiltration rate defined by soil characteristics, an overall "treatment rate" can be defined for a specific device. When storm runoff is applied to the device at rates equal to or less than this rate, 100% is intercepted. At higher applied rates, the fraction of the runoff flow in excess of the treatment rate overflows to a surface water.

If the device also provides storage volume, the volume stored can be retained for subsequent percolation. Overflow to surface waters (runoff that "escapes" the device) occurs only when the available storage is exceeded. Long-term average removal is the net reduction in overflows over the long-term sequence of storms of different size, with different intervals between successive storms.

Performance will obviously vary with the basin size in relation to the area served, with the soil percolation rate, and with the characteristics of local storm patterns.

The analysis procedure described in this section permits one to either (a) evaluate the potential for a specific recharge installation to reduce pollutant loads from a particular drainage area, or (b) develop a general relationship on size or areal density for different levels of pollutant control. Examples of a site-specific approach are presented below; generalized analysis results are presented and discussed later in Section 5.

Level of control is expressed as a long-term average removal of storm runoff flows. The tacit assumption is that the urban runoff which is caused to percolate into the ground is "removed" as a discharge to surface water bodies, as are the pollutants which are present in the runoff. Any percolated waters which eventually reach surface waters through groundwater flow are assumed to percolated waters which eventually reach surface waters through groundwater flow are assumed to have had pollutants of interest removed by relevant soil processes (filtration, biological action), and hence are ignored by the analysis. The validity of this assumption will be influenced by the type of pollutant of interest and local conditions.

As with any model or computation, judgment is required in interpreting the results of this analysis, and in evaluating the overall suitability of recharge devices in a local area. Apart from the factors used in the analysis, considerations such as soil type, slope and stability, depth to water table, etc., will be important determinants of suitability at any site.

It should be noted that the analysis does not address eventual blockage of the soil. The rates assigned should be typical values which can be maintained naturally or by maintenance programs. Neither does the analysis speak to the issue of contamination of the ground water aquifer. Such considerations must be addressed in any actions or decisions related to implementation of this control approach.

The input data requirements for use of the analysis procedure consist of the following:

- Rainfall - mean and coefficient of variation of rainfall intensity. These statistics are developed by the SYNOP program. (See the Appendix for further discussion on this procedure and for a summary of data for a number of cities in different regions of the country.)
- Urban Catchment - area and runoff coefficient (ratio of runoff to rainfall).
- Device Size - surface area provided for percolation, and storage volume.
- Percolation Rate - rate of infiltration provided by local soil - usually reported in inches per hour or gallons per day per square foot. A "Treatment Rate" is defined as the product of the unit percolation rate and the surface area over which percolation occurs.

3.2 ANALYSIS METHOD

Figure 5 illustrates the operating principles involved and summarizes the terminology. The illustation is for the general case; for specific recharge device designs, only the configuration is different. For example, porous pavement would be represented as having a negligible storage volume; an infiltration trench would have the storage area filled with coarse aggregate, and available storage volume reduced to the void volume contained within the gravel or crushed stone.

It is assumed that the device is at the "downstream" end of the urban drainage area it serves, i.e., all runoff from the defined catchment area is routed through the basin.

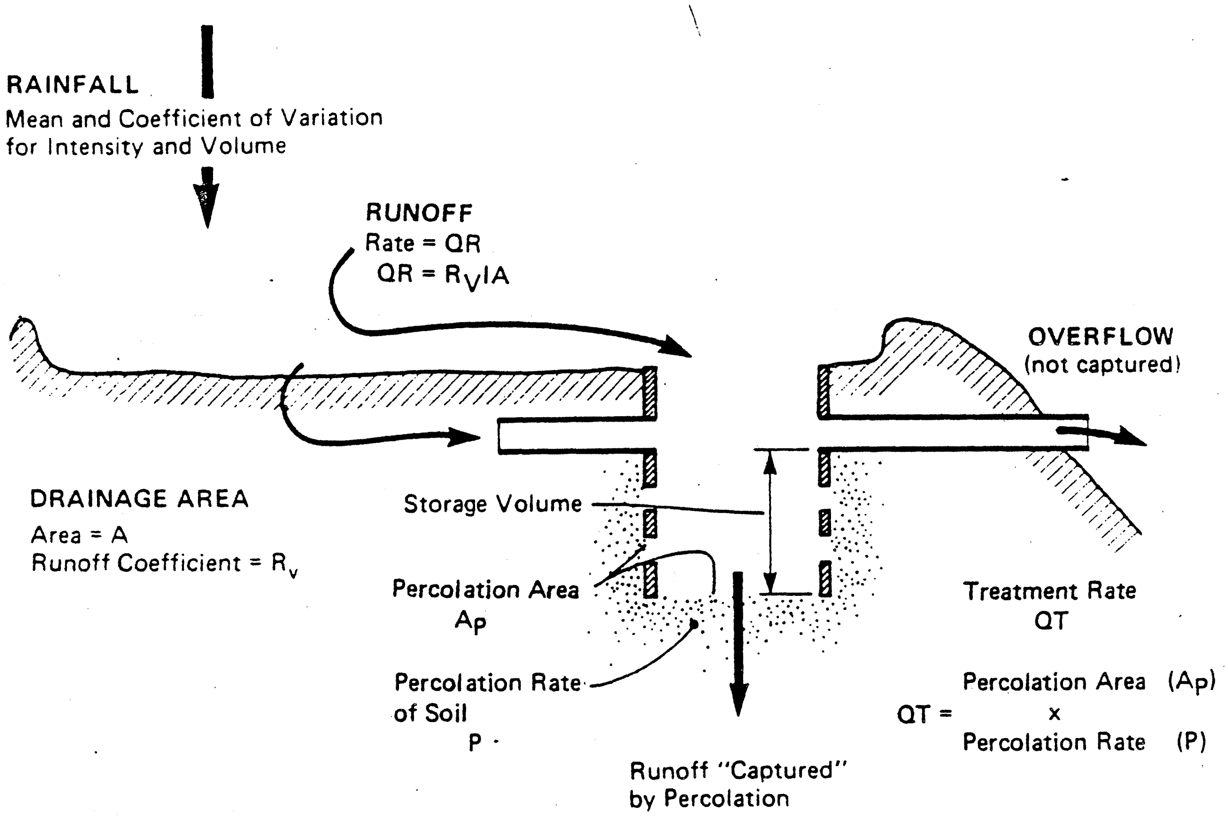

Figure 5. Schematic illustration of recharge device

Long-term performance characteristics are defined as a function of the ratio between the "treatment capacity" (QT) of the device and the runoff rate (QR) from the average storm. It is strongly influenced by the inherent variability in the rate of runoff for different storms -- which is characterized by the coefficient of variation of runoff flow rate (CV_q).

If there were no variability, i.e., if all runoff entered the device at the mean runoff rate, then performance during any event and long term average performance would be the same and would be equal to the treatment capacity provided relative to the applied rate. If treatment capacity were made equal to runoff rate (QT/QR = 1), 100% removal would be achieved. However, where treatment rate is fixed by design and runoff rate is variable, performance is reduced. The greater the variability, the poorer the performance, on average, because of the increasing number and magnitude of events which produce rates greater than the mean runoff rate.

3.3 EXAMPLE COMPUTATIONS

The performance of recharge devices can be projected using the performance curves presented in Section 2. The examples presented in this section illustrate the use of these curves.

3.3.1 Porous Pavement

A. Given

A shopping center has an area of 1 acre. It is all paved surface and runoff coefficient is estimated to be 0.9. Configuration and slopes are such that porous pavement can be installed as part of the catchment paved area and intercept all runoff produced.

The controlling rate of percolation (either porous pavement or the soil below it) is 1 inch/hour.

Storage volume in pores of pavement is assumed negligible.

The site is near Baltimore, Maryland, and rainfall statistics for the area are estimated (from tables in the Appendix) to be:

		Mean	Coef. of Variation
Volume (V)	inch	0.40	1.48
Intensity (I)	in./hr	0.069	1.21
Duration (D)	hour	6.0	1.01
Interval (Δ)	hour	82.0	1.03

B. Required

Estimate the long-term average percentage of storm runoff that would be captured if porous pavement, equal to 10% of the total area of the catchment, were installed.

C. Procedure

Step 1 - Select appropriate performance curve to use for estimate.

- Porous Pavement provides no significant amount of storage volume. Therefore, the device does not capture any volume, and Figures 3 and 4 do not apply.
- Percolation rate, and hence treatment rate (QT) is independent of applied flow rate. Thus, the treatment rate does not depend on flow and Figure 2 does not apply.
- Mode of operation corresponds to that described for FLOW - CAPTURE devices described in Section 2.3. Therefore Figure 1 describes performance.
- Performance estimates are based on QR, QT and CV_q.

Step 2 - Compute mean runoff rate (QR) in cubic feet per hour.

$$QR = (I) * (R_V) * (AREA) * (DIMENSION\ CONVERSION)$$

$$= 0.069 * 0.9 * 1 * 43560/12$$

$$= 225\ CFH$$

Step 3 - Compute treatment rate (QT) in cubic feet per hour.

Percolation rate (P) is 1 in./hr = 0.083 ft/hr

Treatment rate QT = Rate (P) * Area (A_p)

If 10% of the 1-acre catchment area is installed as porous pavement:

$$A_p = 43{,}560 * 0.10 = 4{,}356 \text{ sq ft}$$

$$QT = P * A_p = 0.083 * 4{,}356 = 362\ CFH$$

Step 4 - Compute Design Ratio (QT/QR).

QT (from step 3) = 362 CFH
QR (from step 2) = 225 CFH

QT/QR = 362 / 225 = 1.6

Step 5 - Estimate Long-term Removal.

- In Figure 1, enter horizontal axis at QT/QR = 1.6
- Extend a line vertically until it intersects the curve for the coefficient of variation (from rainfall statistics for intensity, CV_q = 1.25 approximately)
- Extend a line horizontally from this point, and read removal efficiency as approximately 72%

3.3.2 Recharge Basin

A. Given

For a 10-acre residential development, the runoff coefficient is estimated at 0.25. All stormwater runoff from the area is to be routed to a recharge basin.

Minimum basin depth must be at least 2 ft to penetrate a relatively impervious surface soil and reach a layer with good drainage properties. The subsoil has a percolation rate of 2.5 in./hr.

Rainfall statistics for the area are :

		Mean	Coef. of Variation
Volume (V)	inch	0.53	1.44
Intensity (I)	in./hr	0.086	1.31
Duration (D)	hour	7.2	1.09
Interval (Δ)	hour	85.0	1.00

Space constraints limit the basin to a bottom dimension of 25 by 50 ft, or a maximum percolation area of 1250 sq ft.

B. Required

Estimate the long-term average reduction in storm runoff that can be obtained from a recharge basin with the minimum (2 ft) depth.

C. Procedure

Step 1 - Select appropriate performance curve(s).

- Figure 1 applies in this case because treatment rate is based on percolation rate, and is independent of applied flow
- Figure 2 does not apply for the above reason
- Figures 3 and 4 also apply in this case because storage capacity is provided by the device

Step 2 - Compute runoff parameters for mean storm flow rate (QR) and volume (VR).

$$QR = (I) * (R_V) * (Area) * (43{,}560/12)$$

$$= 0.086 * 0.25 * 10 * 3630 = 780 \text{ CFH}$$

$$VR = (V) * (R_V) * (Area) * (43{,}560/12)$$

$$= 0.53 * 0.25 * 10 * 3630 = 4807 \text{ CF}$$

$CV_q = 1.31$ and $CV_v = 1.44$

Step 3 - Compute treatment rate (QT) and the design ratio for treatment (QT/QR).

Percolation rate (P) = 2.5 in./hr = 0.208 ft/hr

Percolation area (A_p) = 1,250 sq ft

$$QT = P * A_p = 0.208 * 1{,}250 = 260 \text{ CFH}$$

$$QT/QR = 260 / 780 = 0.33$$

Step 4 - Compute basin effective volume and the design ratio for storage (VE/VR).

For the minimum (2 ft depth) basin, physical basin volume (VB) is:

$$VB = 1{,}250 \text{ ft}^2 * 2 \text{ ft} = 2{,}500 \text{ cu ft}$$

$$VB/VR = 2{,}500 / 4{,}807 = 0.52$$

Emptying Rate ratio (E)

$$E = \Delta * \Omega / VR$$

Δ is the average interval between storms = 85 hr

Ω is the emptying rate of flow = QT = 260 CFH

E = 85 * 260 / 4,807 = 4.6

From Figure 4, enter horizontal axis at VB/VR = 0.52; extend a line vertically to intersect curve for E = 4.6; then horizontally to read VE/VR on vertical axis. Estimate that effective volume VE is essentially the same as physical volume for this case.

VE/VR = VB/VR = 0.52

<u>Step 5</u> - Estimate performance of recharge basin.

- Removal accomplished by infiltration is estimated from Figure 1 for the conditions

  QT/QR = 0.33 and $CV_q = 1.31$
  % Removed (FLOW) = 24%

- Removal accomplished by storage is estimated from Figure 3 for the conditions

  VE/VR = 0.52 and $CV_v = 1.44$
  % Removed (VOLUME) = 35%

  (This efficiency applies not to the overall runoff from the drainage area, but to the fraction that escapes the percolation process.)

- Overall removal accomplished by the combined infiltration/storage process may be computed directly from the fractions <u>NOT</u> removed by each process.

  Fraction not removed by infiltration

  $$f_Q = 1 - (\%\text{ Removed }/100) = 0.76$$

  Fraction not removed by storage

  $$f_v = 1 - (\%\text{ Removed }/100) = 0.65$$

  $$\%\text{ Removed (overall)} = (1 - [f_Q * f_v]) * 100\%$$

  $$= (1 - [0.76 * 0.65]) * 100\%$$

  $$= 51\%$$

3.4 VALIDATION

Although several of the NURP sites included recharge devices, the data obtained were not sufficient in either scope or extent to provide a suitable basis for use as a validation test for the probabilistic procedure described above.

An examination of the reliability of the performance estimates provided by the procedures presented in this report was conducted by comparing projections for a range of conditions with those produced by an established deterministic simulation model. The model "STORM" was used to generate runoff for a hypothetical urban drainage area, using a long-term (approx. 20 years) hourly rainfall record. This runoff record was then processed by the Storage-Treatment block of the SWMM model, and from the long-term output produced by the simulation, the average percent reduction was computed.

This computation was performed for a variety of basin sizes and soil percolation rates.

Figure 6 compares these results with those produced by the probabilistic analysis procedures.

3.5 DISCUSSION

The procedures described for estimating performance of recharge devices on the basis of size, local soil conditions, and rainfall patterns provide estimates that compare quite favorably with those produced by accepted simulation techniques. They are simple to use and permit examination of the wide variety of alternatives usually desirable in planning activities.

The procedures described provide a basis for quantifying the performance capabilities of a variety of recharge devices, using information that will normally be readily available. However, the suitability of recharge/infiltration systems will vary with location and must be determined on the basis of local conditions.

The possibility of contributing to undesirable impacts on ground water aquifers by enhanced recharge to protect surface waters must be considered on a local basis. Situations have been identified where it has been concluded that the contaminants (and their concentrations) normally present in urban runoff, and which reach the aquifer following percolation, do not constitute a problem or a significant cause for concern. In these situations the practice is encouraged. There are, however, other situations where there are legitimate concerns with the appropriateness of this approach.

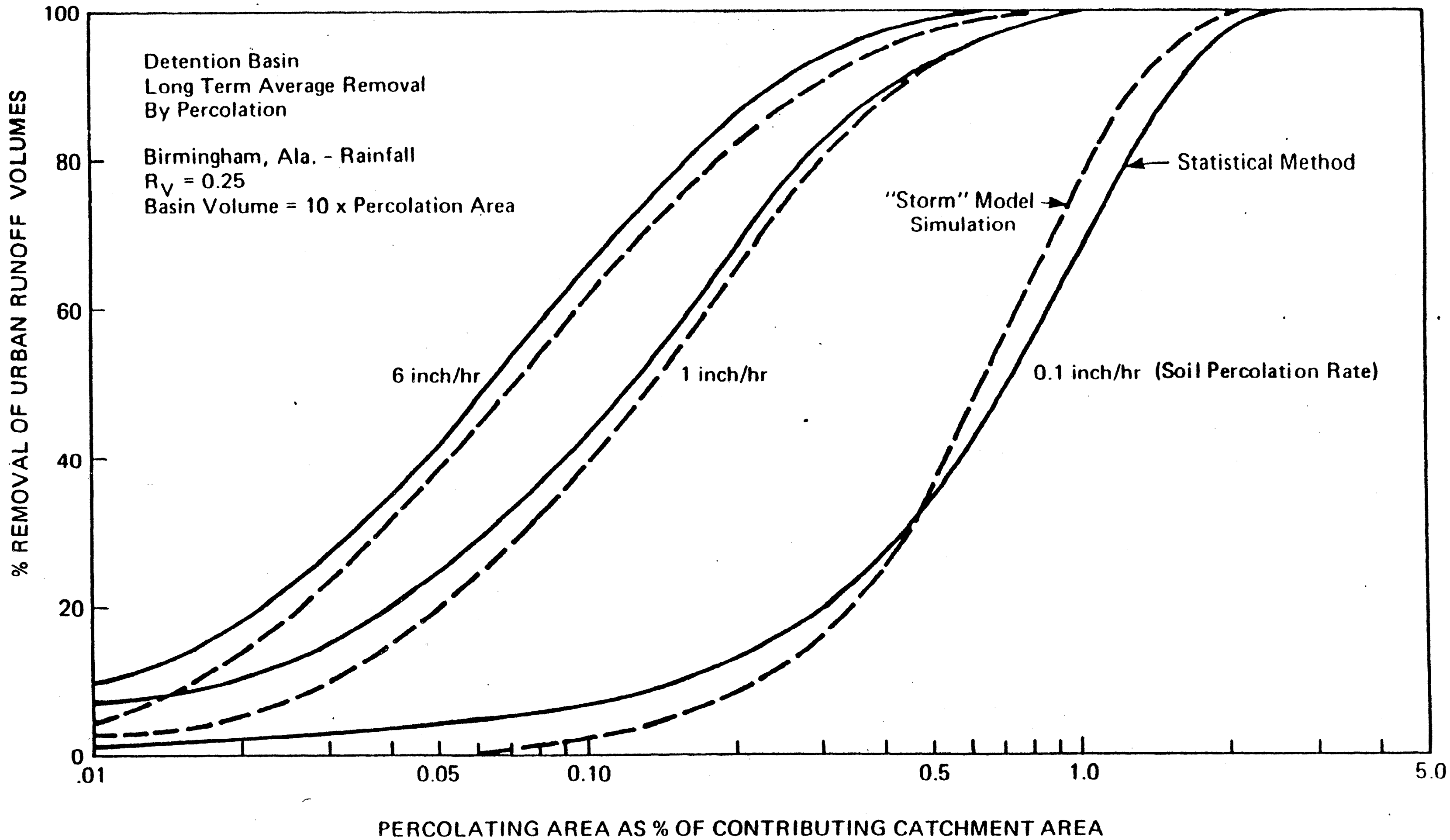

Figure 6. Detention basin performance - long term average removals by percolation - comparison of statistical and simulation methods

The approach may be unsuitable for areas with steep slopes and unstable soils, or areas with water supply wells in sufficiently close proximity to recharge areas.

A tacit assumption in the analysis is that the water table is far enough below the percolation surface that a significant interaction with the temporary mound of ground water, which may form during an event, does not take place.

A further consideration is that percolation rates assigned in the analysis are represenative of long-term conditions, and that significant soil blockage with use either does not occur or is accounted for. Historical experience with recharge basins and with land application of waste waters indicates that progressive blockage is not generally a problem when the soil can be "rested" between applications. The intermittent nature of storms, and the fact that in most areas of the country storm periods occur less than 10% of the time automatically provides such rest periods that help maintain soil permeability.